Phase Engineering in 2D Transition Metal Dichalcogenides

Manish Chhowalla
Rutgers University

Two-dimensional transition metal dichalcogenides (2D TMDs) — whose generalized formula is MX_2, where M is a transition metal of groups 4–7 and X is a chalcogen — consist of over 40 compounds. Complex metal TMDs assume the 1T phase where the transition metal atom coordination is octahedral. The 2H phase is stable in semiconducting TMDs where the coordination of metal atoms is trigonal prismatic. High performance of electronic and opto-electronic devices have been demonstrated with semiconducting TMDs while interesting condensed matter effects such as charge density waves and superconductivity have been observed in bulk metallic 1T phase TMDs. However, stability issues have hampered the study of interesting phenomena in two-dimensional 1T phase TMDs. Recently there has been a surge of activity in developing methodology to reversibly convert 2D 2H phase TMDs to 1T phase. In contrast with typical phase transformation conditions involving pressure and temperature, phase conversion in TMDs involves transformation by chemistry at room temperature and pressure. Using this method, we are able to convert 2H phase 2D TMDs to the 1T phase or locally pattern the 1T phase on 2H phase 2D TMDs. The chemically converted 1T phase 2D TMDs exhibit interesting properties that are being exploited for catalysis for hydrogen evolution reaction, source and drain electrodes in high performance field effect transistors, and as electrodes for energy storage. In this contribution, I will summarize the key properties of 2D 1T phase TMDs and their applications as electrodes for energy and electronics.